

WE CLAIM:

1. A broad-band illuminator for illuminating a sample in an optical metrology apparatus comprising:

5 a first light source emitting radiation over a first broadband emission spectrum;

a second light source emitting radiation over a second broadband emission spectrum, said second light source being substantially transparent over a portion of the first broadband emission spectrum;

10 a first optical system for directing a portion of the radiation emitted from the first light source through the second light source and for focusing the radiation from the first light source to produce a first image of the first light source at a first focal position;

15 a second optical system for focusing a portion of the radiation emitted from the second light source to produce a second image of the second light source at a second focal position, and for relaying the first image of the first light source from the first focal position to the second focal position;

an aperture stop placed at the second focal position; and

20 a third optical system for focusing the radiation transmitted by the aperture stop on the sample

2. The illuminator of claim 1 where both first and second light sources are selected from the group consisting of incandescent, discharge, laser and amplified stimulated emission sources.

25 3. The illuminator of claim 1 where the first and second light sources are selected so that the first and second broad-band emission spectra span at least a portion of the infra-red, near-infra-red, visible, ultra-violet, deep ultraviolet, and extreme ultraviolet spectral ranges.

4. The illuminator of claim 1 where the first and second light sources are selected so that the first and second broad-band emission spectra span at least one of the infra-red, near-infra-red, visible, ultra-violet, deep ultraviolet, and extreme ultraviolet spectral ranges.

5

5. The illuminator of claim 1 where the second light source is selected so that the second broad-band emission spectrum is the same as that of the first light source.

6. The illuminator of claim 1 where the second light source is selected so that
10 the second broad-band emission spectrum differs from that of the first light source.

7. The illuminator of claim 1 where the second broad-band emission
spectrum differs from the first broad-band emission spectrum and both first and second
light sources are selected from the group consisting of tungsten, tungsten-halogen, xenon,
15 mercury, mercury-xenon, deuterium and hydrogen lamps.

8. The illuminator of claim 1 where the first light source is selected from the
group consisting of tungsten, tungsten-halogen, xenon, mercury and mercury-xenon
lamps and the second light source is a deuterium lamp.
20

9. The illuminator of claim 1 where the first light source is a deuterium lamp
and the second light source is selected from the group consisting of xenon, mercury and
mercury-xenon lamps.

10. The illuminator of claim 1 where the first light source is selected from the
group consisting of tungsten and tungsten-halogen lamps and the second light source is
selected from the group consisting of deuterium, xenon, mercury and mercury-xenon
lamps.
25

11. The illuminator of claim 1 where the first and second light sources are Xe
arc lamps.
30

12. The illuminator of claim 1 where the first and second light sources are deuterium lamps.

5 13. The illuminator of claim 1 where the first light source is a tungsten lamp and the second light source is a deuterium lamp.

14. The illuminator of claim 1 where the first light source is a tungsten-halogen lamp and the second light source is a deuterium lamp.

10 15. The illuminator of claim 1 where the first light source is a Xenon lamp and the second light source is a deuterium lamp.

15 16. The illuminator of claim 1 where the first, second and third optical systems employ at least one element selected from the group consisting of transmissive optics, reflective optics diffractive optics and polarizing optics.

17. The illuminator of claim 1 where the first focal position and the second source position are substantially coincident.

20 18. The illuminator of claim 1 where said third optical system creates an image of the aperture at the sample.

25 19. The illuminator of claim 13 where said third optical system is arranged to segregate polarization states and form a polarized image of the aperture at the sample.

20. The illuminator of claim 14 where the third optical system includes a Rochon prism for segregating polarization states.

21. The illuminator of claim 1 where the optical metrology apparatus is selected from the group consisting of spectroscopic ellipsometers, spectroscopic reflectometers, and polarized beam spectroscopic reflectometers.

5 22. A method of illuminating a sample with broad-band radiation using two broad-band light sources, wherein the first light source emits radiation over a first broadband emission spectrum and wherein the second light source emits radiation over a second broadband emission spectrum, different from the first broadband emission spectrum, the second light source being substantially transparent over a portion of the
10 first broad-band emission spectrum, comprising the steps of:

directing a portion of the radiation from the first light source through the second light source and focusing that radiation from the first light source to produce a first image of the first light source at a first focal position

15 focusing a portion of the radiation emitted from the second light source to produce a second image of the second light source at a second focal position coincident with an aperture stop, and for relaying the first image of the first light source from the first focal position to the second focal position; and

directing the light transmitted through the aperture stop onto the sample.

20 23. The method of claim 22 where both first and second light sources are selected from the group consisting of incandescent, discharge, laser and amplified stimulated emission sources wherein said first and second broad-band emission spectra span at least a portion of the infra-red, near-infra-red, visible, ultra-violet, deep ultraviolet, and extreme ultraviolet spectral ranges.

25 24. The method of claim 22 where the focusing and directing functions are achieved using at least one element selected from the group consisting of transmissive optics, reflective optics diffractive optics and polarizing optics.

30 25. The method of claim 22 wherein the illuminating function includes forming an image of the aperture stop onto the sample.

26. The method of claim 20 wherein the illuminating function includes forming a polarized image of the aperture stop onto the sample.

5 27. The method of claim 22 used to illuminate a sample for optical characterization using at least one of the techniques selected from the group comprising spectrophotometry, spectroscopic scatterometry, spectroscopic reflectometry and spectroscopic ellipsometry.

10 28. An apparatus for evaluating characteristics of a sample comprising:
a first light source emitting radiation over a first broadband emission spectrum;
a second light source emitting radiation over a second broadband emission spectrum, said second light source being substantially transparent over a portion
15 of the first broadband emission spectrum;
a first optical system for directing a portion of the radiation emitted from the first light source through the second light source and for focusing the radiation from the first light source to produce a first image of the first light source at a first focal position;
20 a second optical system for focusing a portion of the radiation emitted from the second light source to produce a second image of the second light source at a second focal position, and for relaying the first image of the first light source from the first focal position to the second focal position;
an aperture stop placed at the second focal position;
25 a third optical system arranged to direct the radiation transmitted through the aperture onto the sample and for imaging the aperture at the sample;
a detection system for monitoring radiation reflected from the sample and generating output signals in response thereto; and
a processor for evaluating the characteristics of the sample based on the
30 detected output signals.

29. The apparatus of claim 28 where both first and second light sources are selected from the group consisting of incandescent, discharge, laser and amplified stimulated emission sources.

5 30. The apparatus of claim 28 where the first and second light sources are selected so that the first and second broad-band emission spectra span at least a portion of the infra-red, near-infra-red, visible, ultra-violet, deep ultraviolet, and extreme ultraviolet spectral ranges.

10 31. The apparatus of claim 28 where the first and second light sources are selected so that the first and second broad-band emission spectra span at least one of the infra-red, near-infra-red, visible, ultra-violet, deep ultraviolet, and extreme ultraviolet spectral ranges.

15 32. The apparatus of claim 28 where the second light source is selected so that the second broad-band emission spectrum is the same as that of the first light source.

33. The apparatus of claim 28 where the second light source is selected so that the second broad-band emission spectrum differs from that of the first light source.

20 34. The apparatus of claim 28 where the second broad-band emission spectrum differs from the first broad-band emission spectrum and both first and second light sources are selected from the group consisting of tungsten, tungsten-halogen, xenon, mercury, mercury-xenon, deuterium and hydrogen lamps.

25 35. The apparatus of claim 28 where the first light source is selected from the group consisting of tungsten, tungsten-halogen, xenon, mercury and mercury-xenon lamps and the second light source is a deuterium lamp.

36. The apparatus of claim 28 where the first light source is a deuterium lamp and the second light source is selected from the group consisting of xenon, mercury and mercury-xenon lamps.

5 37. The apparatus of claim 28 where the first and second light sources are Xe arc lamps.

38. The apparatus of claim 28 where the first and second light sources are deuterium lamps.

10 39. The apparatus of claim 28 where the first light source is a tungsten lamp and the second light source is a deuterium lamp.

15 40. The apparatus of claim 28 where the first light source is a tungsten-halogen lamp and the second light source is a deuterium lamp.

41. The apparatus of claim 28 where the first light source is a Xenon lamp and the second light source is a deuterium lamp.

20 42. The apparatus of claim 28 where the first second and third optical systems employ at least one element selected from the group consisting of transmissive optics, reflective optics diffractive optics and polarizing optics.

25 43. The apparatus of claim 28 where the first focal position and the second source position are substantially coincident.

44. The apparatus of claim 28 where said third optical system is arranged to form an image of the aperture stop at the sample.

30 45. The apparatus of claim 28 where said third optical system is arranged form a polarized image of the aperture at the sample.

46. The apparatus of claim 28 where the third optical system includes a Rochon prism for segregating polarization states.

5 47. The apparatus of claim 28 wherein the detection system is selected from the group consisting of spectrophotometers, spectroscopic reflectometers, spectroscopic scatterometers and spectroscopic ellipsometers.

10 48. The apparatus of claim 28 wherein the spectroscopic reflectometer is a polarized beam spectroscopic reflectometer.

15 49. The apparatus of claim 28 wherein the detection system is selected from the group consisting of: spectroscopic reflectometers for measuring the change in magnitude of the radiation at a plurality of wavelengths and spectroscopic ellipsometers for measuring the change in polarization state of the radiation at a plurality of wavelengths.

20 50. The apparatus of claim 28 wherein the detection system is selected from the group consisting of: polarized spectroscopic reflectometers for measuring the change in magnitude of polarized radiation at a plurality of wavelengths and spectroscopic ellipsometers for measuring the change in polarization state of the radiation at a plurality of wavelengths.

25 51. The apparatus of claim 28 wherein the detection system and processor operate to analyze, individually or in combination, output signals selected from the group consisting of: the change in magnitude of the radiation at a plurality of wavelengths, the change in polarization state of the radiation at a plurality of wavelengths, the change in magnitude of polarized radiation at a plurality of wavelengths and the scatter at a plurality of wavelengths.